

**Before the
Federal Communications Commission
Washington, D.C. 20554**

In the Matter of

Amendment of the Commission's Rules with)	
Regard to Commercial Operations in the 3550-)	GN Docket No. 12-354
3650 MHz Band)	

Comments of iPosi, Inc.

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A. Introduction

iPosi, Inc.(iPosi) thanks the Federal Communications Commission for its foresight in proposing this new rulemaking to adopt shared spectrum services. This step opens up innovation thus gives all innovators an opportunity to address policy formulation through comments on this Further Notice of Proposed Rulemaking in the above captioned proceeding.

Introducing our company, iPosi technology is relevant to this proceeding since it provides embedded location and synchronization solutions using advanced assisted GPS/GNSS methods which enable deep indoor sensitivity, ranging and time transfer to solve the dilemma of GPS denied service indoors. iPosi addresses shared spectrum, small cell solutions plus other applications requiring precise deep indoor location determination, for next level applications from geo-crypted data for security, E911, commercial location and timing for network operations to name a few. Relevant to this proceeding, the company also holds proprietary technology and methods to increase the “share-ability” of co-channel resources for dense wireless networks. This added element and solution assures greater incumbent interference protection by obtaining comprehensive measurements of RF losses surrounding each network device that shares common spectrum.

The foundational principles are based on tomographic imaging – a principle in common with medical imaging. Here, its RF based -- the system applies incoming skyward satellite RF signals to act as near-continuous illumination sources that surround a target. These signals just outside are known to a relatively precise level. Using the continuously recovered satellite signals to register loss by 3D angle of arrival, one obtains an image based on transfers through the same building medium for each azimuth and elevation. The system creates an accurate image of vectors which impacts each device’s local transmission loss. This includes the direction of loss relevant to estimating matrix loss values among incumbent and shared network devices. This method is also general enough to apply to extend to carrier frequencies proposed here and outside this FNPRM.

Introducing our position, the scarcity of available broadband mobile spectrum is well known and virtually uncontested. To address this problem, some propose up-rooting existing legacy spectrum users to “clear” spectrum then move it to auction for use exclusively by one entity. Others have proposed clearing spectrum but instead of auctioning to one high bidder, the Commission should assign these resources to allow unlicensed (actually uncoordinated) access by operating with the fewest rules regarding interference outside a newly cleared band or segregating or steering signals to reduce mutual interference. While both proposals may have points of merit in the extreme, neither proposal affords the degree of dynamically determined radio access, stability, future-proof scalability, interference management, or enable natural incentives to improve access efficiency as does the new spectrum-sharing option proposed in this FNPRM.

Also forgotten with either of these “clearing” alternatives is the inconvenient matter of how to finance and who should pay for band clearing and where to then move displaced incumbents elsewhere in the spectrum. Aside from the fact that these bands are to some degree internationally standardized, the estimated time to effect clearing a comparable block of radio spectrum costs the stakeholder incumbents, in this case the Federal government, military and commercial maritime entities, many billions and take a decade or more¹. These findings are a result of objective fact-seeking work by the NTIA and its Office of Spectrum Management who deserve credit for not only establishing the fundamental truths of the need for sharing to serve the nation’s economic welfare but proposing an initial policy framework to set in motion sharing Federal user spectrum responsibly, and provide more than zero-sum alternatives that based on past experience offer little positive benefit.

To that end, “Share” in the context of spectrum has historically had a bad “rap” or reputation because it was never effectively coordinated using 21st Century innovation and advanced tools such as accurate embedded self-surveyed geo-location, deep indoor satellite signal processing, high capacity databases, control automation, and network technologies capable of dispensing radio access rights precisely -- all making it so devices can “share”

¹ An Assessment of the Viability of Accommodating Wireless Broadband in the 1755 – 1850 MHz Band, NTIA Report, March 2012, http://www.ntia.doc.gov/files/ntia/publications/ntia_1755_1850_mhz_report_march2012.pdf

within the same building or same floor. A modern, *intelligently* shared spectrum system, with a common central control point, the Spectrum Access System (SAS) is able to initiate or update radio rights assignments dynamically (if necessary) at millisecond rates, sense the radio propagation environment to accurately determine link quality, or onset of interference among multiple randomly placed neighbors. Thus, the SAS can bring to a central point the computational capacity to determine precisely the level of *harmless* interference under which the shared spectrum system actively limits or avoids detectable harm to Incumbent systems and services.

Further, the Incumbents with primary rights and new entrants proposed in this proceeding, “Citizen Broadband Device” (CBSD) users, can both avail modern automated tools to virtually hide one from the other’s “electrospace”² presence operating on the same frequency band. The new system automation, location and radio sensing assures the incumbents’ radio electrospace when operating across multiple (indeed up to seven) dimensions, and is sufficient to segregate these co-channel communications. As said, both traditional and new electrospace dimensions can create access control for dense (tens of stations per km), dynamic (within milliseconds dispense rights or adjustments), and exploit short ranges (typically 100m outdoors, 30m or less indoors). This is well suited to address indoor, or better termed, ‘in-building’ locations where most wireless data traffic is generated using massively scalable Small Cell systems that can almost instantly tailor coverage and capacity.

Small Cell³ networks that apply the shared spectrum architecture contemplated within this FNPRM are already tightly interconnected and thus can in the next generation form radio resources dynamically and in self-organized fashion to not only meet FNPRM

² A term first coined in 1969 by Henchman who first described the radio spectrum to hold seven dimensions. This was subsequently refined to show this concept can be exercised to define, set radio rights and spectrum policy in treatises by Mr. Robert Matheson, now retired Director of ITS/NIST Radio Labs, Boulder CO. See: http://www.brookings.edu/~media/research/files/papers/2011/3/03%20spectrum%20rights%20matheson%20morris/0303_spectrum_rights_matheson_morris.pdf
http://www.its.bldrdoc.gov/isart/art05/slides05/mat_r/tutorial_a_slides.pdf

³ Small Cell as used here refers to both licensed and unlicensed short range (typically below 100m, below 30-50m indoors) base stations.

objectives of avoiding harmful interference but add important features including improved cross-carrier roaming and enhance indoor location capability.

iPosi supports the three-tier service as proposed in this FNPRM and as originally proposed in the 2012 PCAST Report.⁴ We support within the three tiers the PCAST defined Priority Access (PA) and General Authorized Access (GAA) service levels. This policy attracts a diverse range of networked radio applications, including wireless access to new non-human M2M or Internet of Things solutions. The three-tiered access policy also foresees most or all of the entire 1000MHz envisioned in the PCAST report, so it's future-proof and scalable.

We believe the GAA service tier is only at the first stage of creative radio access rights innovation. For instance, GAA has ample room to grow into micro-exclusive rights protection where cooperative trading among geographically related users (say within a condominium complex, or independently operated stores within a mall) can experimentally test mutual compatibility levels and limits, and once satisfied could enter into private arrangements, perhaps on a larger scale even contractually enforced radio rights that could be technically mediated in the SAS entity.

These new sharing arrangements will be undertaken among local parties who best know their needs and interests, and this automation off-loads the FCC – these arrangements do not require regulatory intervention to succeed. GAA micro-exclusivity is possible through precise knowledge of each GAA site location and its unique indoor (the most prevalent case) radio propagation environment which helps deduce link robustness and interference range.

Fueling this innovation means exploiting spectrum “densification”, which is the concurrent increase in geographic radio node density combined with higher link bandwidth availability. This precept is measured using a figure of merit: **error-free bits delivered per**

⁴ See PCAST, Report to the President: Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth (rel. July 20, 2012) (PCAST Report), *available at* http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf.

hertz per unit area served, or for short bits/Hz/km². As before, there are two more “downstream” strategic design choices: either design networks for greater spectrum re-use by aggressively managing the spectrum’s spatial and temporal dimensions between sending and receiving radios, or rely more exclusively on raising the channel-carrying bit density (which technologists call “higher modulation order”).

The first choice requires architectural changes to orchestrate and thus interconnect the nodes, incorporate a centralized intelligent management entity such as a server complex, program the server complex to manage a large number of distributed nodes, then monitor their link service qualities and contain their neighboring interference effects, all virtually in real time, with exactitude. This choice increases complexity by moving the access control function from a relatively fixed, autonomous operating regime toward sophisticated intelligence that aggressively manages and thus conserves physical layer access (incorporating geo-location, spatial, radio isolation measurements collected continuously at each transmitting node).

The second choice, some might say a more traditional approach, raises the raw information carrying rate of the radio signals. This is proven but it comes at the expense of adding exponentially greater transmission power to overcome smaller margins of noise and self-interference tolerances. This trade-off (among other parameters) was eloquently described by Shannon and his observed law bears his name, Shannon’s limit that in effect describes the efficient frontier of radio and communication physics. Seeking the ultimate Shannon limit makes sense overall (for instance, modern 4G LTE now operate quite close to the Shannon limit), and is still optimal for lower density, continuously transmitting or range-limited radio systems.

As these proceedings address, for the most bandwidth demanding segment of wireless operations all interests seek to move quickly toward higher density, burst-based access radio networks, thus shift system engineering objectives toward organizing surrounding networked radios to now work in unison, to offer the most resource within the allowances of the service tier while still conserving to optimally share the radio resource pool.

This view is not original. It was first expressed in Cooper's Law⁵ which states higher wireless channel capacity is available by exploiting physical access layer optimizations, which in this case are applicable in dense, short range radio systems. Techniques such as reducing same-system interference range and segmenting channels spatially are just two technology levers underpinning Cooper's 'Law' whose corollary posits that wireless *data* delivery has also been about doubling every 30 months since the origin of wireless 100 years ago. This trend continues increasingly through emphasizing greater frequency re-use over sole reliance on increased modulation bandwidth.

In line with these systems engineering advances, intelligently shared spectrum access can take automatically determined location at each remote GAA and PA and when indoor combine this with interior environmental isolation measurements to generate an innovative local radio transmission profile, and a new form of dense network channel state information. This localized RF attenuation or loss profile helps the central SAS achieve greater throughput efficiency while maintaining robustness. It incorporates near real time transmission and receiver customized loss measurements surrounding each radio access node. This will enable more productive control of paths and interference ranges which in turn creates copious *new* spectrum resources.

We now introduce our Comments in response to each of the Commission's questions as posed in the FNRPM, paragraph 63, geo-location.

B. Paragraph 63 Answers and Supporting Comments

- 1. Commission: For the SAS to predict and evaluate potential interference and spectrum availability accurately, it must have accurate location information for all CBSDs. We propose that all CBSDs must accurately report the location of each of their antennas to within ± 50 meters (horizontal) and ± 3 meters (vertical).**
- Based on the prevailing art regarding shared spectrum and cognitive radio systems, we fully agree with the Commission's lead statement. Highest possible location accuracy from stations

⁵ A postulate of radio systems engineering, first stated by Martin Cooper, retired Vice-President and Corporate Director of Research and Development, Motorola, Inc.

and in particular the station antennas are critical to map relative to peers and Incumbent stations or protection zones. Accurate location further assures every station enjoys fair access, avoids potential hidden node effects common to indoor environments, and exposes all stations to the least interference operating on the same spectrum.

- Embedded location determination in each station provides the best method to position and time it within large scalable networks. This allows prediction of inter-station losses as well assure the interference range does not cross into incumbent receivers.
- To capture locations and related inter-cell loss variables, it is essential that the geo-location database in the SAS support a local array of approximately $N*(N-1)/2$ path loss profiles given N stations, each with a distinct known location. These can be treated locally which eliminates a large number of superfluous paths that produce power below reception thresholds thus are immaterial residuals for describing the interference environment.
- Every radio path decays with distance, but every link is unique so this decay is also in unique amounts. For general systems with both radio nodes outside using a range of free space to clutter propagation models, location coordinates including elevation are sufficient. When one or both nodes are indoors, short segments of the path have very non-uniform attenuation where loss based on distance can be much more when rays enter or exit buildings.
- For example, the first or last 5-30 meters of the indoor to outside transmission path – a typical distance value range between an interior station and an the outer structural wall of the building -- will impose between 5 to 50 dB⁶ of additional within those short distances, a far higher attenuation than the equivalent outside attenuation in the same urban environment. We address a way to exploit this localized attenuation for purposes of enhanced sharing and density deployments later in our Comments.
- Setting the horizontal error to be within 50m is highly desirable. This appears to match the granularity anticipated with dense urban network CBSD deployments. Industry standards bodies are targeting 5G system deployments forecast to start deploying in 2020 and expect to deliver throughput per user of at least 1Gbps⁷. Current 4th and then later 5th Generation wireless seeks to deliver broadband data up to 100Gbps per km²⁸. This implies about 1Gbps per 100m square area which is about the ultimate range of current indoor small cells up to 30-50m range between the access point and mobile devices.
- CBSD fixed stations and their antenna locations are feasible to position in most indoor and in-building sites provided the CBSD station have location capability equal or similar to the Commenter's embedded location technology solution. More details of this technology and its integration with current LTE OTDOA ranging and Unlicensed WiFi standards are contained in the appendix referencing the recent E911 indoor location report filed by this Commenter.
- Location-aware CBSD equipment can be either an access device that interacts with mobile equipment, or a connection layer device that connects access devices back to an operator's network. In the case of access, it is expected that CBSDs will be configured and operated as

⁶ This equates to a decrease of 3 to 100,000 times in power, and is attributable to transmission loss, reflection and diffractive interactions in either direction of propagation between the in- and outdoors.

⁷ EU METIS 5G requirements, among various, retrieved at <http://www.en.tek-nat.aau.dk/News+and+events/Show+news/important-step-towards-5g.cid94784>

⁸ EU METIS 5G requirements, op cit. 7

indoor Small Cells and thus serve E911 needs to locate mobiles in or outdoors. When indoors, CBSDs will likely provide standards based location signal protocols to determine the indoor locations of nearby mobiles.

- Regarding the Commission's proposed location accuracy specifications, a common 3D location accuracy specification for both E911 indoor location and shared spectrum systems where the vast majority of GAA devices are expected to operate indoors is favorably self-reinforcing. A common accuracy standard is also beneficial, since it would likely increase the rates of urban customer adoption of shared spectrum equipment with integrated indoor E911 location and sync, thus benefitting users and public safety interests. Finally, end-customers are better served with a less ambiguous and common location standard.
- Operators have incentives to sell type accepted equipment for E911 and provide a variety of standards-based connections back into their networks through existing or future backhaul technologies and solutions. Since CBSDs are similar if not identical in application, and should also provide or enable indoor E911, the same architectural solution applies.
- We recommend the Commission consider and accept for SAS managed CBSD location references 'an estimated location error. The location accuracy yield factors will ultimately determine in the E911 indoor location proceeding. Since the E911 proceeding is still being deliberated, final accuracy specifications await final deliberation and notice.
- If the Commission were to decide to set more relaxed location accuracy standards, we recommend the same horizontal and vertical error limit values but consider alternative yield values if necessary to accommodate both E911 and this spectrum sharing proceeding.

2. Commission: The proposed horizontal geo-location requirement is consistent with a similar requirement in the TVWS rules.⁹

- We agree with the intents of this proposal to ensure accurate location update in the case of a change of fixed CBSD station position. We recommend in the interest of practical service operations that moving a CBSD to a new location would only have to be given enough time to report its new position and estimated location error if moved to another position.
- First we recommend when a CBSD perhaps more nomadically deployed CBSDs that are moved from the initial installation simply be allowed any amount of time necessary to re-register its location within *known* (sometimes referred to as the estimated location error) horizontal and vertical accuracies before it be allowed to transmit. A re-located fixed CBSD would then be allowed to transmit under SAS control as soon as the new position is profiled and new transmission rights delivered based on compatible operation at the new location.
- Operationally the SAS has capability to establish operation based on not just a point location of the new antenna, but is able to evaluate a contiguous set of positions bounded in three dimensions referred to as a 3D position uncertainty (usually an error ellipse, sometimes referred to as an ellipsoid).
- With certain technologies such as the Commenter's, the accuracy improves (and the uncertainty reduces) with time on the order of hours to a day or two. Thus obtaining a final position of greatest accuracy may take several hours especially for cases where the CSBD is installed

⁹ See 47 C.F.R. § 15.711(b).

indoors. However, the SAS can still provide rights to the transmitter based on a reduced accuracy location.

- In certain indoor locations the least uncertainty and greatest accuracy may take even up to a day or two. In such cases, the rule ought to allow CBSD transmission over the wider error or uncertainty range provided the power or frequency parameters assigned to the newly positioned CBSD at any location within the horizontal or vertical uncertainty will not cause additional interference.
- Therefore, we recommend modifying this proposed rule to not set a specific time limit so long as the SAS is able to assign rights immediately to a new location even if the accuracy is less than ultimately expected.

3. Commission: We seek comment on these proposals, including potential costs and benefits. Is this degree of accuracy feasible with current technology?

- This degree of accuracy is feasible for most all indoor and outdoor site deployment cases that use assisted indoor GPS/GNSS solutions such as the Commenter's.
- To also address realities of the size of the task, there will be many exceptions given a virtually unlimited number of situations across 6M US structures not to mention approximately 100M residences. Obvious exceptions include underground sites or sites at the lowest few floors surrounded by much taller buildings within the densest, most obscured urban surroundings.
- The Commenter has started challenge tests within the CSRIC E911 indoor location test bed which is relevant here. It is in the process of developing test protocols for recommendation to the committee and has met with certain work group committee members to develop an appropriate small cell location based test that will address both CBSD and mobiles.

4. Commission: Should we (the Commission) require greater accuracy?

- The proposed 50m horizontal 3m vertical location accuracies are appropriate for reasons already stated in this and the E911 Indoor location accuracy NPRMs. Depending on the outcome in the E911 Indoor Location rulemaking regarding yields and timeframes, we believe it is important to have a consistent accuracy for small cells that address both rulemaking objectives to ensure least cost, earliest commercial realization, and not confuse end-customers and other stakeholders with dissimilar location requirements.
- Beyond ensuring similar geo-location accuracy mandates, we see no compelling reason for requiring higher accuracy than proposed in this FNPRM. In fact it is much more valuable to obtain an accuracy measure of the immediately local RF propagation environment and radio isolation for indoor CBSD equipment. Such channel state information will have more impact on power and frequency rights assignment than raw geographic location accuracy.
- It is expected that a high percentage, perhaps 90%, of GAA devices will operate indoors, and it's likely that a majority of PA devices will also be indoors. This forecast is based on current experiences by operators and customers' deploying today's advanced Small Cells. The Commenter's solution makes it feasible at each CBSD measure indoor RF isolation that is resolved into vectors with loss coefficients across relative azimuth and elevation at each PA or GAA device in which the Commenter's equipment is embedded.
- Indoor RF isolation can be precisely determined and directly adds to the loss using outdoor clutter (such as Longley Rice) or general free space path loss propagation models to be used in

the SAS. Once the combined in- and outdoor attenuation losses are summed, the SAS then dispenses proper levels of transmission rights, still consistent with fully protecting Incumbents and optimizing PA or GAA interference levels.

- This combined RF isolation and location factor will automatically raise shared spectrum throughput while ensuring no interference to incumbent systems, and acceptably low interference incidents among densely deployed shared-spectrum devices.
- The accuracy of the Commenter's RF isolation, channel state measurements are approximately within 3 dB error margin of actual indoor attenuation. The Commenter uses a novel method to sound frequencies similar to the radio carrier frequency and is measured over a hemispherical range of azimuths and elevation directions away from the radio node. The value can be more precisely translated if desired for a finer estimate of carrier frequency loss coefficients applying loss versus frequency measurements based on composite building materials such as a comprehensive report issued in 1997 by NIST¹⁰. We recommend not attempting translation due to relatively little difference thus relative little error at the FNPRM frequency of 3.55-3.7 GHz. This step not only simplifies but favorably biases the indoor channel state isolation values so there is several dB additional loss margin¹¹. This conservative treatment ensures that indoor attenuation measurements taken at the CBSD do not cause increase in interference by under-reporting building isolation and attenuation.
- While the CBSD nodes are fixed and general building losses also remain fixed, there can be slowly changing or episodic variations in penetration loss. The proposed RF isolation measurement solution continuously provides updated measurements. The Commenter's solution also takes into account other factors such as the CBSD antenna pattern when measuring interior loss and isolation.

For further perspective on the sensitivity of accuracy on interference level, the Commission's proposed absolute geo-location errors (expressed as the number of meters from a true, fixed position), first for horizontal error:

- For a 50m horizontal error impacts a protection zone that is 1km away by raising incident power (assuming the CBSD error is maximally in the direction of the protection zone) crossing the zone boundary by about 10%, or about .4dB of increased power. A 50m error to a receiving point 200m away (which is more likely), could with no other path impediment see interfering power rise as much as 77% or 2.5dB from each surrounding co-channel CBSD.
- Without indoor propagation loss, the SAS model relies only on urban clutter or free space path loss models which are more likely to significantly overstate the true CBSD power incident on protected receivers. Overstating incident power arises when path losses are underestimated. This prediction bias can result in real, indeed permanent, under-utilization of the shared spectrum.
- Hybridized¹² barometric pressure altitude measurements will likely be useful, provided limits to

¹⁰ Report No. 3, "Electromagnetic Signal Attenuation in Construction Materials", William C. Stone October 1997 Building and Fire Research Laboratory National Institute of Standards and Technology Gaithersburg, Maryland 20899

¹¹ Due to the fact and seen in the NIST report that virtually all building materials and thicknesses tested add loss as the carrier frequency transmitted through these materials rises.

¹² By hybridization, this means using a combination of GPS/GNSS, interior ranging, and barometric sensing methods.

vertical accuracy are recognized¹³. Of several accuracy factors, barometric pressure calibration should be located within the same air column, which requires on the same or at most an adjacent floor.

- On the matter of less accuracy, we recommend inclusion of estimated location error which the position determination system from systems similar to the Commenter's offers. This provides the network and SAS a means to adjust transmission rights according to excess error but not necessarily reduce or curtail rights based on maintaining adequate interference mitigation using an expanded error perimeter. So for instance while a 100 m horizontal error is not preferred outcome, a CBSD reporting this level of estimated error could still be allowed an appropriate level of transmission rights subject to increase once its location error is ultimately reduced.

5. Commission: What effect do the accuracy requirements have on actual spectrum efficiency and the ability of the SAS to manage interference potential among different users?

- As discussed above and summarized here, small error changes have relatively small impact on protecting the Incumbent receivers which are far more affected by correct measurement of indoor CBSD RF isolation. CBSDs that are close, within a few hundred meters, are likely to be impacted more by lack of measured RF isolation measurements.
- CBSD site location accuracy and RF isolation measurements are both necessary to increase shared spectrum efficiency.
- A typical excess RF loss factor¹⁴ for a CBSD transmitting at 3.5 GHz located indoors typically incurs local interior losses between 30-40 dB based on typical building materials and other reflective and diffractive path effects at these carrier frequencies. This loss should not be simply assumed; it must be accurately measured due to significant variation, as each site is different. The loss in every direction can also be quite different without actual and currently updated measurements.

6. Commenter's Additional Point and Example: Benefits of Capturing Measured Building Isolation on Incumbent Service Protection

- If accurate indoor attenuation measurements at the CBSD are known, then the protection distance between the transmitter and the Incumbent maritime radar protection zone can be substantially reduced by adding the accurate in-building loss relevant to each CBSD in the SAS. Each isolation profile is specific to each CBSD.
- In the table below, a range of calculations covering likely coastline protection zone distances are shown with different representative through-building penetration loss values. Using a free space loss model to determine outdoor protection distance, the table value columns calculate the required geographic distance to achieve the same overall signal attenuation as needed in free space given in column 1.

¹³ See iPosi FCC comments in this document, Section D, Appendix.

¹⁴ As used here, the loss attributable to the interior building RF penetration loss(es) in excess of the path loss based on an outdoor path of the same distance to the victim receiver. This may relate to the loss encountered from the PA or GAA device transmitter for estimating accurate interference range or impact, or it may also include a second instance of interior building loss encountered by the receiver end of a GAA or PA link.

- We use a free space square law decay model versus an expected higher loss exponent, typical for low urban and suburban environments (for conservatism), and the likelihood of free space cases over shoreline and higher site situations. But even without these higher loss conditions, the benefits of indoor isolation measurements will be similar.
- To illustrate, if a CBSD is indoors and at that site location the building loss is 40 dB -- an additional loss or isolation based on the local indoor environment – with the loss vector in the direction of the Incumbent service protection zone, which correspond to the Reference distances found in the leftmost column (note the same as the next column representing no excess path loss, that only includes the baseline free space path loss, or FSPL). That compares to the far right column, the need attenuation to protect the intensity of power entering the protection zone will reduce from 100 to 1 km or from 5 km to 100m and interpolated values between. These representative loss values enable substantially more coastal region operation for CBSDs using measured losses.

		Protection distance with the added building loss using free space (d ²)							<-Attenuation dB
	ref d(Km)	0	5	10	15	20	30	40	
Normal outdoor protection distance ref d(Km)->	5	5.0	2.8	1.6	0.9	0.5	0.2	0.1	<-Km
	10	10.0	5.6	3.2	1.8	1.0	0.3	0.1	
	15	15.1	8.5	4.8	2.7	1.5	0.5	0.2	
	20	20.1	11.3	6.3	3.6	2.0	0.6	0.2	
	30	30.1	16.9	9.5	5.4	3.0	1.0	0.3	
	40	40.1	22.6	12.7	7.1	4.0	1.3	0.4	
	50	50.2	28.2	15.9	8.9	5.0	1.6	0.5	
	75	75.3	42.3	23.8	13.4	7.5	2.4	0.8	
	100	100.3	56.4	31.7	17.8	10.0	3.2	1.0	

- Today in the US, the coastal zone is home to 123M or 39% of the US population¹⁵. This area is also contains among the higher density zones of work and living sites, according to NOAA in excess of 450 persons per square mile (excluding Alaska). Though we lack hard data, it seems safe to assume that in general the population density and thus GAA and PA densities will be yet higher drawing closer to coastline populated areas.
- Beside accurate location and RF isolation information it is highly desirable for the SAS to dispense rights that reduce aggregate interference from a number of CBSD devices transmit at time slots that are ordered as much as possible to be at different times. For this to be effective, all GAA and PA devices should operate on a common time base to schedule independently operating transmitters to offset transmission at different times (within the allowed frames and time slots of the radio air interface or protocol) in order to reduce cumulative interference peaking effects.
- Since this synchronous timing function is normally part of the geo-location sub-system, we address it here as part of this FNPRM geo-location paragraph comments and recommendations.
- Therefore, our recommendation for rules in this proceeding urges the Commission include in its final rules 1) mandate capability within the GAA, PA and SAS equipment that provides a universal synchronous timing capability, 2) use this capability to maximally offset transmissions from one another (and within local areas) in time so as to reduce interference effects of

¹⁵ “National Coastal Population Report, Population Trends from 1970 to 2020”, NOAA, retrieved on July 5 at <http://stateofthecoast.noaa.gov>

superimposed signals formed by stations' simultaneous co-channel transmissions, and 3) use as accurate and universally available timing source that is also compatible with existing (including legacy systems) standards on a universal time reference such as embedded GPS/GNSS.

7. Commission: Would the proposed geo-location requirement place undue burden on equipment manufacturers or SAS operators?

- The cost of the location and time synchronization subsystem is less expensive if embedded into the CBSD site which for other reasons requires location and synchronization functions to offer seamless networking, mobile indoor location, E911. This technology in the Commenter's solution is the least expensive solution for GAA or PA devices. These are similar to Small Cell platforms which based on market demand have good reason to believe is the most economical solution.
- Some OEM Small Cell vendors have shared figures with this Commenter regarding the cost of external synchronization or location capabilities, which may or may not include network and maintenance services in addition to capital expenses. Depending on location and building ownership the range for such capital expense is \$250-2000 per Small Cell. This range is deemed to be high and is a level that impedes adoption of Small Cell deployment. In some cases it moves customers toward less spectrally efficient non-synchronous alternatives. The Commenter reserves publishing prices but its solution cost is much less.

8. Commission: Is such a requirement reasonable to control the interference environment among users?

- Both geographic location and measurement of indoor RF isolation parameters are critical to realize compatible spectrum sharing among CBSD devices. Both measures are important to manage optimal sharing and increase interference protections for the higher service tiers proposed in this FNPRM.

9. Commission: Is there a different timeframe for reporting that should be used?

- For reporting changes in site location it will be important to immediately notify the SAS based on indication of a change in location, which may trigger an update to transmission rights for the re-located and re-installed CBSD.
- It is likely that many changes on the same floor, perhaps even in the same building will have minimal changes occur in transmission rights. Moving to a different building will generate a new interference profile. Based on experience, the typical time for a new location fix to be generated and settle within a 50 m horizontal error is relatively fast, for indoors often within a few minutes or if residential single family homes, it is much less. In the meantime transmission rights based on a provisional, less accurate position can be dispensed almost immediately after the fix is established.
- The critical factor is to report the location and RF isolation characteristics to the SAS in as time sensitive fashion and allow for updates since these measurements may change with time. The SAS can usually extend similar transmission rules and modify them as isolation and accuracy measurements improve within a matter of minutes or hours, with the finest granularity of RF isolation vector definition in days at some interior locations.

C. Summary and Recommendations

iPosi makes the following recommendations to the Commission derived from our comments above.

Location Accuracy. iPosi recommends the Commission, as it previously set forth make consistent accuracy specifications for general E911, its proposed rules within the scope of the E911 Indoor Location Accuracy Notice of Proposed Rulemaking,¹⁶ and these proposed geo-location rules for this FNPRM 3.5GHz Shared Spectrum proceeding.

We expect 3.5GHz shared spectrum systems and individual stations will be used similarly to current licensed and unlicensed small cells or access points and thus be extensively deployed indoors. Next generation small cells using either classic spectrum assignments or incorporate this new shared spectrum access all provide critical indoor fixed and mobile device location references, and we expect many will also provide location ranging based on widely standardized radio network protocols, such as LTE Release 9. This release incorporates important OTDOA mobile range measurement capability useful for indoor (and outside) location.

Common Location Accuracy Requirements with E911. Since the new shared spectrum systems are expected to handle a similar number of E911 calls, it seems logical to make the location accuracy requirements identical. Though 50m horizontal and 3m vertical are demanding these requirements are tenable for Small Cell networks using the Commenter's technology. A single indoor accuracy specification reduces cost and complexity and minimizes ambiguity.

Regarding the tolerances themselves and the questions or rational value raised in this proceeding under Paragraph 63 of this FNPRM or the Indoor Location Accuracy NPRM, we share in large part the Commission's view that error tolerances of 50 meters horizontal and 3 meters vertically match the scale of the interior area and floor elevation of most buildings. This is important to effect E911 rescue in a number of the approximately 200M plus E911 wireless calls made annually, many surmised to occur at indoor locations.

These same location error tolerances for E911 match reasonably the inter-cell resolution of high density in-building networks so they may reach high data throughputs indoors (seeking by 2020 to reach peak throughput densities of 100Gbps per km²). These systems can exploit short interior wireless range, use new 3.5GHz or similar frequencies that afford 10-100MHz channel bandwidths, and contemplate sharing spectrum across generally licensed independently owned GAA devices.

For 3.5 GHz shared spectrum systems, the error sensitivity interference range to device elevation is less than for the demands of E911. This Commenter expressed the challenges to

¹⁶ GN Docket No. 07-114

achieve 3m accuracy inside tall buildings in its Indoor Location Accuracy NPRM Comments which can be seen from the link in the Appendix. We recommend a balance be struck on the performance and error yield (e.g., 67% transitioning to 80%) of indoor elevation accuracy based on barometric sensor performance, calibration such as GPS/GNSS calibration and manual floor designation for interior small cells.

Automated Verifiable Geo-location: iPosi recommends the Commission adopt that the form of geo-location use an automated and verifiable method to reduce location errors and avoid deliberate or unintentional antenna/cell locations that arise with manual entry. Manual entry of location should be a last resort and if necessary verified independently to assure system reliability, interference containment and robustness.

Estimated Error of Location, its Addition to the SAS, and Its Usage by the SAS: Estimates of path loss are only as good as the quality of inputs to the prediction model. Another subtle but important “goodness” statistic is the estimated location error, which represents the extent of uncertainty in meters from a calculated position point. This statistic can be used to adjust transmission rights based on assessing the maximum error to further reduce interference potential based on the closest point based on extending the estimated error to the full extent toward the victim receiver. iPosi therefore recommends using geo-location solutions which produce the estimated location fix and an estimated error statistic that the SAS can use to adjust transmission rights to raise flexibly interference margin and reliability.

Include Indoor Building RF Attenuation Measurements. iPosi recommends localized indoor sensing capability that enables each CBSD to accurately measure surrounding indoor RF isolation as part of the SAS determined loss and interference posed by each CBSD station. This step will add sharing capacity, and increase interference protection to both Incumbent and new CBSD devices by incorporating local environmental loss values.

Include Wide-Area, Locally Available Synchronization in the CBSD to Reduce and Manage Aggregate CBSD Interference. iPosi recommends the Commission also adopt rules that each CBSD be synchronized to a common time base to govern transmission times in order to reduce concentrations of neighboring cell interference peaking (also known as “spectrum whitening”). Using conventional access protocols, this enables the transmitters using a common frequency to offset their times of transmission relative to neighboring device transmissions thus reduce aggregate interference in denser areas.

D. Appendix

1. Comments, iPosi, Inc. E911 Indoor Location Accuracy NPRM (Docket No. 07-114)
Retrieve at: <http://apps.fcc.gov/ecfs/document/view?id=7521122795>

2. Reply Comments, iPosi, Inc. E911 Indoor Location Accuracy NPRM (Docket No. 07-114)
Retrieve at: <http://apps.fcc.gov/ecfs/document/view?id=7521293152>

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